

Development and management of coastal lagoons

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ABSTRACT

This paper focuses on coastal lagoons as a resource subset within the coastal area. In an effort to develop an understanding of some of the problems and opportunities associated with the development and management of such environments and their adjacent uplands, some basic approaches and management principles are discussed.

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RÉSUMÉ

Développement et gestion des lagunes côtières

Le présent article traite des lagunes côtières en tant que ressources inhérentes à la région côtière. Afin de mieux comprendre les problèmes et opportunités qui résultent du développement et de la gestion de tels milieux et des « zones humides » associées, une attention spéciale est portée sur les principes élémentaires de gestion de la zone côtière.

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INTRODUCTION

Of all the physiographic features that compose the shorelines of the world, coastal lagoons are one of the most distinctive. Indeed, their wide distribution along the coastline of all continents — from polar to tropical zones — makes it imperative to study and seriously consider them within any planning endeavour. They have been considered comparatively simple systems (Colombo, 1977 *a* and *b*) in a delicate natural balance, and therefore easily susceptible to detrimental environmental impact from pollution or by other human activities which, if uncontrolled, would exceed their caring capacities and their abilities to sustain various kinds and levels of use.

Coastal lagoons are integral parts of a larger and more complex system characterized by a highly dynamic biophysical environment (composed of terrestrial, aquatic and biological support systems which follow a complex array of natural processes) continuously undergoing change. Any planning scheme for their development and management should therefore be based on an integrated approach which considers the lagoon within the widest context of its surrounding areas as well as all the components and interactions between the subsystems. Thus, the geographical definition of the planning and management area should encompass the body of the lagoon, its catchment area, the region in which it exists, as well as the adjacent marine environment.

Coastal lagoons have provided a diversified economic base in relatively large coastal sectors of many countries. Primarily, they have provided significant food resources. Fishing and mariculture, for example, have constituted one of the oldest forms of coastal resource exploitation and among other things they serve as a valuable source of protein in various countries. Lagoons also provide recreational and aesthetic enjoyment, which in certain countries, are also two of the fastest growing uses. In some countries they have been used as harbour facilities, growing in a number of cases into the focus around which centres of population and industry have developed. They also derive use as the repositories for wastes, including treated and untreated household and industrial wastes, and surface drainage waters from urban and rural land.

As long as the multiple uses on a lagoon are moderate, they may be accommodated. As demands intensify, strains appear. Conflicts inevitably and continually arise in the management of a lagoon as a multiple purpose resource. In resolving such conflicts, a number of management alternatives have to be considered and the likely effects of each of them have to be assessed. The prediction of beneficial and/or detrimental effects requires in-depth information and comprehensive understanding of the cause-effect relationships of three distinct but interacting elements: a) the natural ecosystem; b) the socio-economic and cultural base; and c) the regulatory and institutional infrastructure. The integration of natural processes and human use pat-

terns, which requires a set of continuing management and regulatory policies, is of vital importance for achieving the integrated management of both resources and uses, as well as for anticipating the capacity of the area to absorb future demands.

AN INTEGRATED APPROACH TO COASTAL LAGOON MANAGEMENT

There is no ideal formula that represents the management process of a coastal lagoon. As an integral part of the coastal zone, lagoons can be subject to the broad coastal area management process, providing special consideration are taken to consider the outstanding characteristics of the resource subsets.

Let us make a brief summary of the issues that are most relevant to the management process (Vallejo, 1977).

A coastal lagoon :

a) is an environmental unit where the structures and functions of the bio-physical system have a leading role in determining the natural resource potential as well as the capacity of the lagoon to sustain various uses. Therefore, within a management perspective there is a critical need to define the physical, chemical and biological thresholds and limits of the lagoon system ;

b) is an area whose economic use depends on maintaining the stability of the productive base and thus requires a judicious organization of the spatial distribution of activities and of the forms and intensity of resource use ;

c) is a geo-economic space subject to varying degrees of human impact ranging from reclamation of wetlands to dumping of industrial waste. Within a management perspective, it is imperative to ascertain the present and projected social and economic forces at-work in the region in order to be able to predict possible chains of qualitative and quantitative effects that might affect the lagoon system ;

d) because of the vulnerability of lagoons to a buildup of contaminants and other ecological disturbances, in principle they used maximum protection controls (Vallejo, 1977). Therefore, in management terms, water quality is a central topic concerned with the water body of the lagoon, the whole catchment area and the marine adjacent waters ;

e) it is an area where the economic activities determined both locally (e.g., intensive aquaculture) or externally to the lagoon system (e.g., building a dam in the catchment area), can have various types and levels of impact. Therefore, the environmental assessment of the ecological implications of indiscriminate use of space is vital. Its absence can lead to consequences that can have an effect beyond the geographic area of the lagoon.

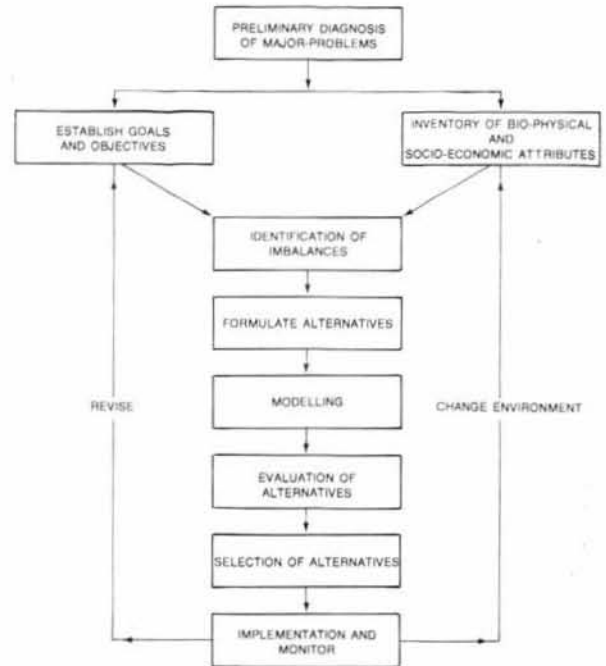
All these issues should be contemplated and incorporated into the management process. If successfully done, the management process would then run through the following steps : preliminary diagnosis of major problems, establishing goals and objectives, inventory phase, identification of imbalances, development of alternatives, selection of models, analysis of alternatives, selection of alternative, implementation and monitoring (see Fig.).

A basic requirement of the management process is the need for adequate and timely data for decision making. These includes :

— base line data on the environmental attributes of the resource area and of coastal processes that may act as constraint on development objectives. This could be presented cartographically and made to depict critical and sensitive features ;

— base line data on economic activities in the vicinity of the lagoon and in the catchment area, including current economic data and socio-economic projections ;

— assessment of the existing demography and projections of population growth associated with development objectives to determine socio-economic needs as well as probable pollution loads ;



Figure

The planning management process.

Source : Nassau-Suffolk Regional Planning Board (1976).

— an inventory of present land-use patterns, and on the basis of development objectives, projected land-use ;
 — an inventory of present waste discharges, indicating type and quantity of pollutants produced by each type of land use.

These data will be applied in the various phases of the management process. A great part of the success of the management process will depend on the information base. Specifically its extent and quality, and its usefulness in answering questions that may arise in the development of the resource.

The planning process

The first step in developing or simply managing the resource is to define goals and objectives on the basis of a preliminary diagnosis of the major problems. In the case of a lagoon which is to be utilized as a harbour facility, for example, the crucial developmental issues may be geared toward selecting land and water alternatives which maintain or permit other critical lagoonal functions.

The second step is the inventory phase. It entails the collection of various kinds of data. Extensive survey through on-site observation or remote sensing, or both, will be needed to describe, analyse and evaluate environmental features and processes, as well as a survey of present economic activities and land-use patterns in or adjacent to the lagoon that have or may have an impact on the environmental characteristics that maintain the functions of the lagoon. This should be complemented with demographic data and socio-economic projections.

The next step is to identify imbalances that impede or retard planned development. In a coastal lagoon where industry, tourism, commerce, etc. are fully developed, the allocation of limited resources to satisfy various needs is the most significant question of the management process. As long as the demands on a lagoon are moderate, they may all be accommodated within its area. As demands intensify however strains appear. Conflicts of interest inevitably and continuously arise in the management of a lagoon as a multi-purpose resource if demands continuously increase with no effort being made to introduce checks and balances. The identification of the bio-physical attributes and their natural capability to sustain use, as well as the assessment of the demands for activities based upon various types of projec-

tions such as economic growth and population, will be the basis to detect and measure present and future imbalances as well as for anticipating the capacity of the area to absorb future demands.

To meet development objectives and to solve or limit the incidence of imbalances, alternative courses of action should be formulated. The generation of alternatives can be based on a variety of criteria, such as water quality. In most cases, there may be more than one alternative available or a combination of related alternatives.

Models can assist considerably in the process of selecting alternatives. They aid in understanding the effects of activities and structures upon the environment by evaluating the impact of alternative actions (Ketchum, 1972). For example, through a model, the relationship between the natural capability of the lagoon system to sustain various uses and the impact of projected discharges of waters under varying assumptions of levels of economic activity and population growth, can be examined. Among the types of models recommended in various studies of estuarine areas are the Land Activities Model: Shapiro (1975), the Environmental and Resource Capability Model, the Waste Discharge Model and the Transport Model: The Division of Natural Resources and the Environment (1973).

The selection of alternatives should be done on the basis of the economic and socio-political feasibility of implanting an alternative. As a result various evaluation techniques have to be employed. For economic analysis cost-benefit techniques are widely used. By itself, however, cost-benefit analysis is not sufficient but should be complemented by an analysis of the socio-political feasibility. This may take the form of an analysis of cost and potential benefits of each alternative (e.g., the cost involved in port development might be considerably more than that of development of aquaculture. However, the revenues of expanded port operations might substantially exceed, in the medium term, those derived from aquaculture); and the analysis of public attitudes regarding the use of the lagoon exclusively for one or the other activity.

The implementation phase has been identified as one of the weakest points in the management process (Rondinelli, 1978). Some of the causes to which this has been attributed include questions relating to the mandates of the different administrative agencies, lack of communication between scientists and administrators, lack of adequate information to effectively support the planners in their decision-making process, etc. These problems are magnified in the coastal area because it involves a multiplicity of jurisdictions, both geographical and functional. To this should be added the interrelationships between the public and the private sectors (Vallejo, 1979; 1981). The first task of this phase should therefore be to make an inventory and analysis of existing legal, administrative and institutional arrangements that impinge on the plan's implementation. The second task will be to determine what new arrangements or modifications to the existing arrangement are required for plan implementation. Finally the nature and types of governmental action required for the implementation of the selected alternatives and the institutions that will be involved. For example, if the alternative chosen designates that dredge spoil should be placed in barrier areas subject to erosion, then the management's task is to assure that there is sufficient spoil which can be used for this purpose and that this actually gets done.

USES AND MISUSES OF COASTAL LAGOONS

Extractive activities

Since early times, lagoons have played an important role in man's activities. Some archaeological and historical investigations (Isaacs *et al.*, 1973) have proved, for example, that coastal lagoons in Southern California were the foci of prehistoric human interaction and settlement. A shell-gathering culture seems to have persisted around lagoons, at

least intermittently, for nine millennia. This form of resource use can be found in various lagoonal environments of the world. Indeed, according to Lankford (1976) man's first impact on the natural lagoon system was based on his need to produce salt for preserving food or for dietary purposes. Beginning with the collection of natural precipitates and later through the use of primitive evaporation pans, filtration mounds and lead canals constructed along the shoreline, salt collection might have initiated the first permanent settlements along coastal lagoons. Today, for example, in the Republic of Korea salt ponds found along the western coastline contribute a significant share of the nearly 900,000 t of salt Korea produced in 1978 (Sung-Woo Kim, 1981).

Cultivation of fish and shellfish is one of the oldest forms of lagoon utilization. Colombo (1977 *a* and *b*) in stating the conditions required to conduct long term fishing in a lagoonal environment states *inter alia* that it is necessary to maintain the lagoonal environment in a condition suitable for their rapid growth.

Mining is another extractive activity that takes place in or around coastal lagoons. In Fiji (Richmond, 1981), because of the lack of suitable and close limestone deposits, dredging of coral sand in the barrier reef lagoon is the sole method of supply of CaCO₃ for the cement industry. This practice has been going on for some years; with the company going from site to site after exhausting each one. Only recently has the company been required to carry out baseline studies to determine the sediment transport within the lagoon and the rate of recharge to areas already mined. *Agriculture* is probably the second priority use after fishing and cultivation of fish and shellfish. It is a traditional activity for which some lagoons were reclaimed because of shortage of land. Today, the lands surrounding lagoons are used for agricultural practices in various countries. For example, in Benin and Nigeria, the sand belts have fishing villages and coconut plantations. Mangrove is cut for tanning material, timber and fuel. Also, swamp cultivation is developing where salt content of the soil is low (Offurum, 1980).

Other uses and activities

Apart from the extractive activities, lagoons have a variety of other uses: navigation, ports, recreation, residential development and industry, water supply, waste disposal, etc. The level and pattern of usage depends mainly on the type of lagoon and the stage of economic development. The nature and effects of related activities points to the overall problem of compatibility of uses. We know that some uses can co-exist with others, provided the level of use is maintained, there are no changes in use/practice, or new uses are not imposed on a previously compatible set of uses. Very few uses are exclusive, such as wildlife preserves or aquaculture, when it is intensively pursued. Finally, displacing a non-coastal dependent use to an inland location might involve great economic cost, innovative engineering, and public and political support. All these risks should be weighed on the basis of a sound knowledge of actual and potential impacts of present and projected activities on the lagoonal environment.

The use of a lagoon as a navigational corridor is closely associated with industry, commerce and port functions. For example, the Porto-Novo lagoon in Benin provides a direct waterway to Lagos, the most populous and best equipped port in Nigeria. It has been reported that Lagos lagoon, which has several islands and a permanent outlet to the sea and is fed by the Ogun River and fringing mangroves affords many development advantages if properly managed (Offurum, 1980). In those countries where channel dredging is needed it may produce siltation, increased turbidity and also alter the hydraulic system of the lagoon. If the dumping of spoil takes place along the side of the channel, this may affect the lagoon ecosystem in various ways. It may restrict and alter the circulation patterns and the exchange of

marine and fresh water. By enclosing or dividing the natural lagoon environment, productivity may also be lowered.

Recreational use of lagoons in concomitant to the growing use of the coastal zone for water-based activities for outdoor recreation. It is a major economic force in developing countries where the beach and shoreface areas in coastal barriers are used for fishing, camping, etc. Boating and swimming are restricted to the calm and sheltered waters of the lagoons, away from strong wave action. Among the most relevant impacts are those related to construction in the barrier coasts, due to high erosional susceptibility, as well as frequent tidal inundation and extreme potential for storm damage. Liquid and soil disposal in beach areas also have a high potential for pollution of aquifers due to the high permeability of the loose sand and shell, and to the adjacent marine environment. Also important will be the impact of tourism upon the socio-economic environment of the area, as well as the intensive investment and use characteristics of this type of development.

In both developing and developed countries, lagoons that are distant from urban centres are designated for national parks or national reserves. This is the case with the northern coast of Honduras (Cruz, 1977) where a large lagoonal system is still in pristine stage. It has more than 850 sq. km of great tourist potential — considered one of the largest in Central America — based on its wildlife, archaeology, ethnology and history. Presently, it is only used by artisanal fishermen who take advantage of the fish resources of the lagoons.

Port expansion presents the highest potential for conflicts; it will involve development of channels, dredging and soil disposal as well as filling, draining and construction. In terms of environmental effects, both liquid and waste disposal, dredging, draining and soil disposal are the activities which precipitate the most complicate chain of effects resulting in the alteration of water quality and of biological processes on which commercial fisheries, mariculture and recreational use depend.

In heavily populated areas, *residential and industrial development* is frequently intense around lagoons. This might involve offshore, coastal and inland construction, reclamation of wetlands, related excavation, filling, draining and revegetation. The major problem associated to this type of use is the great potential for disruption or destruction of the primary value of lagoons due to changes in the configuration of the water basin and to the discharge of domestic and industrial waste, sewage and/or other hazardous materials. These two can affect two critical conditions of paramount importance: the maintenance of water quality and the circulation and flushing patterns of a lagoon.

Closing remarks

The anticipated growth of populations and the level of economic activities along the coastal areas of the world will have a significant effect on lagoonal environments. These have proven to have some outstanding characteristics as well as a diversity of natural resources — but also they have a varying and generally restricted capacity to sustain existing and potential uses and associated activities.

The number of possibly conflicting uses may increase as more activities are developed and the multiplicity of present and potential uses and activities is not properly planned and managed. In this respect, there are various methods to identify and assess the impact of human use upon the coastal environment. Under the broad title of interaction matrices — network diagram, co-axial matrix, composed-matrix, etc., — present or proposed activities with associated environmental conditions and effects can be deduced. In turn, they can also show how all the resultant environmental changes will affect other activities or further human use (The Division of Natural Resources and the Environment, 1972). Basically, they are very useful tools to identify, describe, and possibly quantify the network of interactions between cause-condition-effect links so that the relevant importance of each network link can be estimated (Koppelman, 1981; Nassau-Suffolk Regional Planning Board, 1976; and Ellis *et al.*, 1973).

Coastal lagoons have proven to be quite complex systems from the planning and management perspective. While the variety and complexity of coastal lagoons impose extreme variations from place to place, the fundamental principles of management are applicable to all of them. Neither an ecological-environmental approach nor an economic one alone can provide the solution to their development problems and priority conservation issues.

There is a need to apply an integrated approach that takes into consideration economic, social and environmental goals. Only through a comprehensive, rational decision-making process, in which planners look to the future in order to guide the decision-makers in making current decisions, can successful results be obtained.

Planning and management decisions should view coastal lagoons as a natural system that are part of the coastal area, and as such, they are integrated to a much wider context of regional dimensions. The conceptual framework of the coastal area planning and management process is a valuable one and its application should be seriously considered in order to assure a more effective use of the lagoon systems as a multiple resource.

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